A Retrospective Cohort Study of Race and Ethnicity, Pre-pregnancy Weight, and Pregnancy Complications

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Abstract

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Objective: To examine relationships between race/ethnicity, pre-pregnancy overweight/obesity status, and pregnancy complications: gestational diabetes (GDM), preeclampsia, and cesarean-delivery.

Methods: We conducted a large retrospective population-based cohort study among mothers who delivered a singleton live birth in hospitals that participated in the Obstetrics Clinical Outcomes Assessment Program database (N=57,144). Race/ethnicity was categorized into mutually exclusive groups of Non-Hispanic White (NH-W), NH African-American (NH-AA), Hispanic, NH Asian (NH-A), NH American Indian/Alaskan Native (NH-AI/AN), and NH Native-Hawaiian/Other Pacific Islander (NH-NHP). Pre-pregnancy overweight/obesity status was defined as body mass index (BMI) $\geq 25 kg/m^2$. Information on pregnancy complications was ascertained from medical records. We used unadjusted and adjusted stratified Poisson regression models with robust standard errors to estimate relative risk (RR) and associated 95% confidence

intervals (CI). We used stratified models and models with interaction terms to examine interactions between race/ethnicity and overweight/obesity status on pregnancy complications. **Results:** Majority of women were NH-W (52.2%). Similarly, most were overweight/obese, pre-pregnancy (52.1%). Compared with NH-W, NH-AA, Hispanics, NH-A and NH-NHP had higher risk of GDM (aRR:1.36, 1.44, 2.12, and 2.42 respectively) while Hispanics, NH-A, and NH-NHP had a lower risk (aRR:0.89, 0.53 and 0.64 respectively) of preeclampsia (all p-values<0.05). Women with pre-pregnancy overweight/obesity had higher risk of cesarean-delivery, GDM, and preeclampsia (aRR:1.58, 1.92 and 2.57 respectively, p-values<0.05), when compared with normal-weight women. In stratified models, among overweight/obese women, NH-AI/AN women had an elevated risk of preeclampsia as compared to NH-W (aRR:1.36; 95%CI:1.04-1.76). This association was not present among normal-weight women (aRR:0.64; 95%CI:0.24-1.70). Similarly, among overweight/obese women, but not normal-weight women, Hispanic and NH-NHP had a lower risk of preeclampsia (aRR:0.79; 95%CI:0.70-0.89 and aRR:0.60; 95%CI:0.39-0.94, respectively) and NH-AA had a greater risk of GDM (aRR:1.29; 95%CI:1.09-1.53) when compared with NH-W women. Among all race/ethnicities, but not AI/AN and NH-NHP, overweight/obese women had an increased risk of GDM and preeclampsia, respectively, when compared with normal-weight women (p-values<0.05). The multiplicative interaction terms between race/ethnicity and pre-pregnancy overweight/obesity status were significant for all three pregnancy complications (interaction p-values<0.05). **Conclusion:** Race/ethnicity modifies associations of pre-pregnancy overweight/obesity status with pregnancy complications. Conversely, pre-pregnancy overweight/obesity status modifies associations of race/ethnicity with pregnancy complications.

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INTRODUCTION

The increasing prevalence of maternal overweight and obesity is a major challenge in today's world. In the US, in 2011-15, more than half of all pregnant women were overweight (body mass index, BMI 25-29.9 kg/m^2) or obese (BMI ≥30 kg/m^2), with only 45.1% women entering the pregnancy at normal weight (BMI 18.5–24.9 kg/m^2).[1] In the US, prevalence of overweight or obesity among women 20 years and older increased from 50.7% in 1988-1994 to 68.1% in 2013-2016.[2] [3] Maternal pre-pregnancy overweight or obesity status has been associated with pregnancy complications including gestational diabetes (GDM), preeclampsia,[4] [5] and, cesarean deliveries.[6] The prevalence of overweight or obesity varies by racial/ethnic groups.[7] [8] Compared with Non-Hispanic (NH) Whites, NH African-Americans, Hispanics, and Pacific Islanders have a higher prevalence of obesity, while Asian-Americans have a lower prevalence.[7] [8]

Preeclampsia and GDM are major pregnancy complications that are associated with maternal and fetal morbidity and mortality. Preeclampsia affects 2-8%[8] of pregnancies while GDM affects 1-14%[9] of pregnancies in the US. In addition, 31.9% of live births in the US, in 2016, followed cesarean deliveries.[10] Cesarean delivery is associated with increased risk for hemorrhage, infection, thromboembolism, future reproductive implications for the mother, and potentially long-term health implications for the baby, all of which are associated with significant maternal and fetal morbidity, and possibly mortality.[11] Studies have shown that the incidence of GDM, preeclampsia, and cesarean deliveries vary by race. When compared with NH White women, NH African-American women are specifically at a higher risk for severe preeclampsia and superimposed preeclampsia, while Asians/Pacific Islanders have lower risk.[12] Hispanic women are at elevated risk of GDM, compared to NH Whites (6.8% vs. 4.5%,

respectively).[13 14]African-American, Hispanic/Latino, and Native American mothers are more likely to have cesarean deliveries, compared with NH White or Asian mothers.[13 15]

Despite the racial/ethnic disparities in overweight or obesity status and pregnancy complications, the relationships between maternal race/ethnicity, pre-pregnancy overweight/obesity, and pregnancy complications are not clear.[13 16 17 18 19] For instance, previous reports indicate associations of pre-pregnancy obesity with preeclampsia or GDM were either present or stronger among NH White women, but not African American women.[16 17] However, these observations were not consistent across studies.[13 18 19] In addition, research in this area has several gaps that will be addressed by the current study. [16 17 20 21] First, most previous studies were conducted in a non-US setting and may not be representative of the growing diverse population of the US. Second, studies were in general limited to two comparison groups, usually comparing NH White with African-Americans or Hispanics,[16 20] or treated two distinct race/ethnic categories as one.[22] There was limited assessment of associations across multiple race/ethnic groups in a single study.[20] Third, the studies mainly examined birth outcomes of baby such as infant-mortality and birthweight, but did not examine cesarean delivery, which complicates 1/3 of pregnancies in the United States.[22 23] Finally, past studies were mostly based at a single institution (limiting generalizability)[18] and had insufficient power to assess statistically significant interactions between race/ethnicity and pre-pregnancy overweight or obesity status on obstetrical outcomes.[19]

The objective of this study was to examine interactions of race/ethnicity with pre-pregnancy overweight or obesity status on pregnancy complications (GDM, preeclampsia, and cesarean delivery). Better understanding of these relationships can facilitate tailored public

health messages and preventative interventions to serve the diverse American obstetric population.

METHODS

Study Design and Setting

We performed a large retrospective population-based cohort study, using data from the Foundation for Health Care Quality's Obstetrics Clinical Outcomes Assessment Program (OB COAP), an ongoing multicenter, clinician-led, voluntary, collaborative quality initiative in Washington State.[24] We used data collected from January 2014 to November 2018. Twenty-two hospitals and clinics participated in the program, for all or part of the study period. These hospitals and clinics had a broad mix of acuity and delivery volume and were sites of nearly a third of births in Washington State.

The Western Institutional Review Board (WIRB; Olympia, Washington), which provides ethical review services for academic and non-academic institutions, determined in 2015 that OB COAP is not engaged in human subjects research and therefore is exempt from institutional review board review.[25] A determination of exempt status for this study was also made by the University of Washington Institutional Review Board. No identifiable data were used in the current analysis.

Study Subjects

The cohort in this study comprised mothers who delivered a singleton live birth at one of the 22 facilities during the study period (N=85,307). Individuals with missing data on race or ethnicity, as well as those reporting multiple race/ethnicities were excluded (N=18,644). We also excluded individuals with implausible or missing values for BMI (N=4,944), or missing values for preeclampsia (N=3,632), GDM (N=9,021), or cesarean delivery (N=805). Among 57,286 remaining women, we excluded individuals with preexisting diabetes and hypertension

(N=1703) from analyses involving GDM and preeclampsia. We also excluded women with elective cesarean section (N=142) from analyses involving cesarean delivery. Our final analytic population consisted of 55,583 mothers for analyses involving GDM and preeclampsia, and 57,144 mothers for analyses involving cesarean delivery.

Data Sources

Data were collected by trained abstractors from medical records of women who delivered during the study period at institutions participating in the OB COAP. Variables were defined by criteria established by OB COAP (e.g., substance abuse history was defined as illegal substances and/or inappropriate use of controlled substances started or continued during the pregnancy) and, where applicable, by the medical diagnosis (e.g., GDM). Data were entered into a cloud-based standardized data tool and underwent real-time quality checks and frequent audits at the site and aggregate levels.[24 26]

Exposures, Outcomes and Adjustment Variables

The main exposure, race/ethnicity, was defined as a self-report of race/ethnicity of the mother. Two different variables in the database—Race and Hispanic/Latino ethnicity—were used to create six mutually exclusive groups of race/ethnicity: NH White, NH African-American, Hispanic, NH Asian, NH American Indian/Alaskan Native (AI/AN), and NH Native-Hawaiian/Other Pacific Islander (PI).

The other main exposure, pre-pregnancy overweight or obesity status, was defined using pre-pregnancy BMI, which was calculated in the database from the self-report of pre-pregnancy weight, if available, or from the initial weight collected from mothers during the first prenatal visit, divided by the height of the individual in meter squared. Pre-pregnancy BMI was defined as

underweight (BMI < 18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25.0-29.9 kg/m^2) and obese (BMI ≥30.0 kg/m^2), based on categories recommended by the Center for Disease Control and Prevention and the World Health Organization.[3 27] For the current analyses, we focused on pre-pregnancy normal weight and pre-pregnancy overweight or obesity status (BMI ≥ 25.0 kg/m^2) in line with previous studies.[28 29]

The primary outcomes that were studied were pregnancy complications: GDM, preeclampsia, and cesarean delivery. Information on these clinical diagnoses were obtained from medical records. GDM was defined as clinical diagnosis of GDM as recorded in Labor and Delivery record.[30] Pre-eclampsia in the OB COAP database was defined as hypertensive diseases of pregnancy (the combined clinical diagnosis of pre-eclampsia and gestational hypertension). Cesarean delivery was identified using mode of delivery recorded from Labor and Delivery Record in the database.

A number of potential confounding variables, which may be associated with race/ethnicity and/or pre-pregnancy overweight or obesity status, as well as pregnancy complications were included *a priori*. The following continuous variables were included: maternal age at labor and delivery admission (in years) and parity. The following binary variables were included: government health insurance (Medicare, Medicaid, Military Health Care, State-Specific Plan or Indian Health Service) (yes/no), substance abuse history (illegal substances and/or inappropriate user of controlled substances started or continued during the pregnancy) (yes/no), nicotine use (yes/no) and alcohol use (yes/no). A categorical variable indicating the 22 hospitals in the study was also included. We did not include gestational age at delivery in the models as it may be part of the causal pathway or closely related to causal

pathway relating either exposure (race/ethnicity or overweight or obesity status) with pregnancy complications (GDM, preeclampsia, and cesarean delivery).

Statistical Analyses

First, socio-demographic and pregnancy-related characteristics of the mothers in the study were summarized overall, stratified by race/ethnicity (NH White, NH African-American, Hispanic, NH Asian, NH AI/AN, and NH Native-Hawaiian/Other PI) and stratified by pre-pregnancy BMI categories. Mean and standard deviations were used to summarize continuous variables, while count and percentages were used to summarize categorical variables.

We examined independent associations of race/ethnicity and pre-pregnancy overweight or obesity status with GDM, preeclampsia, and cesarean delivery using unadjusted and adjusted (adjusted for potential confounding variables described above) Poisson regression models with robust standard errors. Underweight women were included in all the analyses as a separate category (where applicable) but their findings were not reported. The regression models were used to estimate relative risk (RR) and 95% confidence intervals (CIs). Next, two sets of unadjusted and adjusted stratified regression models were fit, as described below, to examine interactions between race/ethnicity and pre-pregnancy overweight or obesity status on pregnancy complications—GDM, preeclampsia, and cesarean delivery.

In the first set of models, we fit the unadjusted and adjusted regression models examining associations of race/ethnicity with pregnancy complications among groups stratified by pre-pregnancy overweight or obesity status. For each of the three outcomes, models compared the risk of each pregnancy complication among NH White women (referent) to risk among women

in the other race/ethnicity groups within the same pre-pregnancy overweight or obesity status group.

In the second set of models, we fit unadjusted and adjusted regression models examining associations of pre-pregnancy overweight or obesity status with pregnancy complications among groups stratified by race/ethnicity. For each of the three outcomes, models compared risk of pregnancy complications between normal-weight women (referent) and overweight/obese women, within the same racial/ethnic group.

Finally, we fit an interaction model to test the statistical significance of multiplicative interactions between race/ethnicity and pre-pregnancy overweight or obesity status as follows. The model included terms for race/ethnicity, overweight or obesity status, and their product (race/ethnicity * overweight or obesity status), adjusted for the confounders described above. The p-value of the interaction term was used to determine statistical significance of the interaction on the multiplicative scale.

We performed several *a priori* planned sensitivity analyses to assess robustness of our results. First, we fitted stratified models among overweight and obese women separately. With the consideration that BMI cutoffs may not accurately reflect overweight or obesity status in women of certain race/ethnicities, we conducted a sensitivity analysis using (a) BMI as a continuous variable, and (b) re-defining overweight or obesity status for Asian women using cut points suggested by WHO for Asian populations: underweight (BMI < 18.5 kg/m^2), normal weight (BMI 18.5–22.9 kg/m^2), overweight/obese (BMI ≥ 23 kg/m^2).[31] We repeated our primary analysis for the outcome of cesarean delivery by limiting the analyses to women with no previous history of cesarean delivery. To alleviate concerns that the missing observations for pregnancy complications (GDM, preeclampsia, and cesarean delivery) could be an outcome not

observed (instead of an outcome missing), we re-ran our primary analyses for the interaction models by considering women without outcomes (missing data) as women who did not experience the pregnancy complications.

In all analyses, statistical significance was determined using the cut off p value<0.05. All statistical analyses were conducted using R studio software (Version 3.5.2).

RESULTS

The average age of study participants was 29.6 years (*Tables 1 and 2*). The majority of participants were NH White (52.2%), followed by Hispanics (21.5%), NH Asians (19.3%), NH African-Americans (4.4%), NH AI/ANs (1.4%) and NH Native-Hawaiian/Other PIs (1.2%). The majority of participants were overweight (27.6%) or obese (24.5%). The prevalence of GDM, preeclampsia, and cesarean delivery in the study population were 10.3%, 8.9%, and 16.1% respectively.

Compared with NH White women, NH African-American women (adjusted RR, aRR 1.36; 95% CI: 1.16, 1.59), Hispanic women (aRR 1.44; 95% CI: 1.31, 1.58), NH Asian women (aRR 2.12; 95% CI: 1.97, 2.28) and NH Native-Hawaiian/Other PI women (aRR 2.42; 95% CI: 1.92, 3.04) had greater risk of GDM. Hispanic women (aRR 0.89; 95% CI: 0.80, 0.99), NH Asian women (aRR 0.52; 95% CI: 0.46, 0.59) and NH Native-Hawaiian/Other PI women (aRR 0.64; 95% CI: 0.42, 0.98) had lower risk of preeclampsia compared with NH White women. NH African-American women (aRR 1.72; 95% CI: 1.55, 1.91), NH Asian women (aRR 1.17; 95% CI: 1.09, 1.24) and NH Native-Hawaiian/Other PI women (aRR 1.81; 95% CI: 1.49, 2.19) had greater risk of cesarean delivery, compared with NH White women (*Table 3*). Overall, maternal overweight or obesity status was associated with a greater risk of GDM (aRR 1.92; 95% CI: 1.80, 2.05), preeclampsia (aRR 2.57; 95% CI: 2.36, 2.80), and cesarean delivery (aRR 1.58; 95% CI: 1.50, 1.67) (*Table 3*).

In models stratified by pre-pregnancy overweight or obesity status *(Table 4 and Figure 1),* among overweight/obese women, but not normal-weight women, NH African-Americans had a greater risk of GDM (aRR 1.29; 95% CI: 1.09, 1.53 and aRR 1.21; 95% CI: 0.81, 1.80, respectively) when compared with NH White women. The greater risk of preeclampsia that was

observed among NH AI/AN, compared with NH Whites, was observed among overweight/obese women (aRR 1.36; 95% CI: 1.04, 1.76), but not among normal-weight women (aRR 0.64; 95% CI: 0.24, 1.70). Similarly, among overweight/obese women, but not normal-weight women, Hispanic and NH Native-Hawaiian/Other PI women had a lower risk of preeclampsia (aRR 0.79; 95% CI: 0.70, 0.90 and aRR 0.60; 95% CI: 0.39, 0.94 respectively) when compared with NH White women. While observed estimates (and associated 95% CIs) for the other associations of race/ethnicity with pregnancy complications among overweight/obese women and normal-weight women had some differences, in general, the magnitude or directions of associations were similar.

In models stratified by race/ethnicity *(Table 5 and Figure 2),* a greater risk of GDM was observed among overweight/obese women, compared with normal weight-women, in all race/ethnicities groups except among NH AI/AN women (aRR 2.11; 95% CI: 0.86, 5.19). The strength of the association of overweight/obesity with GDM was greater among NH African-American women (aRR 2.80; 95% CI: 1.85, 4.24) than among NH Asian women (aRR 1.79; 95% CI: 1.61, 1.99). Similarly, greater risk of preeclampsia was observed among overweight/obese women of all racial groups except NH Native-Hawaiian/Other PI (aRR 4.76; 95% CI: 0.99, 22.96), compared with their normal-weight counterparts. The strength of the association of overweight/obesity with preeclampsia was much greater among NH AI/AN women (aRR 4.70; 95% CI: 1.69, 13.11) than among other race/ethnicities. Among White, African-American, Hispanic, and Asian, but not NH AI/AN (aRR 1.90; 95% CI: 0.98, 3.67) or NH Native-Hawaiian/Other PI (aRR 1.32; 95% CI: 0.84, 2.17) women, overweight/obese women had a greater risk of cesarean delivery when compared with normal-weight women. While observed estimates (and associated 95% CIs) for the other associations of pre-pregnancy

overweight/obese status with pregnancy complications among the different racial/ethnic groups had some differences, in general, the magnitude or directions of associations were similar.

The p-value indicating multiplicative interactions between race/ethnicity and overweight or obesity status was significant for all pregnancy complications we considered: GDM ($p<0.001$), preeclampsia ($p<0.05$) and cesarean delivery ($p<0.05$).

In sensitivity analyses, we found some notable findings. Interactions of race/ethnicity with continuous BMI were significant only for GDM (data not shown). As expected, associations between race/ethnicity and pregnancy complications were stronger among obese women, when compared with similar associations among overweight women (data not shown). When applying the Asia Pacific BMI cut off for Asian women, the proportion of overweight/obese women increased from one-third to one-half of total Asians. In this sensitivity analyses, the associations of overweight/obesity with GDM and cesarean delivery were similar to what we observed in the primary analyses, while the association of overweight/obesity with preeclampsia was attenuated (Table 6). The interaction effect was no longer significant for cesarean delivery and preeclampsia but remained for GDM (not shown). In general, the results of other sensitivity analyses were consistent with our main findings although risk estimates and corresponding 95% confidence intervals were slightly changed.

DISCUSSION

In the current study, race/ethnicity and pre-pregnancy overweight/obesity status were independently associated with pregnancy complications. We also observed evidence of interaction between race/ethnicity and pre-pregnancy overweight or obesity status on GDM, preeclampsia, and caesarean section. The race/ethnicity-related greater or lower risk of preeclampsia was observed only among overweight/obese women, but not among normal-weight women. On the other hand, greater risk of GDM, preeclampsia, or caesarean delivery among overweight/obese women, compared with normal-weight women, were not similar among all race/ethnic groups.

Comparison of findings from previous studies with our findings show a mix of similarities and differences. Similar to our findings, previous reports show differences in associations between pre-pregnancy overweight/obesity and pregnancy complications across racial/ethnic groups. Snowden et al reported that the risk of GDM and preeclampsia associated with pre-pregnancy obesity status was higher among NH White women when compared to similar associations among other racial/ethnic groups.[17] In that study, among overweight women and normal-weight women, but not among obese women or morbidly obese women (BMI $\geq$ 40 kg/m^2), Hispanic women had a greater risk of preeclampsia (aOR 1.20; 95% CI: 1.09, 1.31 and aOR 1.33; 95% CI: 1.23, 1.44 respectively) as compared to NH White women.[17] Our study, on the other hand, found that Hispanic women had a lower risk of preeclampsia when compared with NH White women, among overweight/obese women but not among normal-weight women. Another retrospective cohort study conducted among Missouri residents found that obese NH White women had a greater risk of developing preeclampsia as compared to their normal weight peers (adjusted Odds Ratio, aOR 3.1; 95% CI: 2.9, 3.2).[16] The magnitude of the association of

obese status with preeclampsia among African-American women, compared to their normal weight peers, was not as strong (aOR 2.1; 95% CI: 1.9, 2.4).[16] Snowden et al. reported that the magnitude of the association of GDM when comparing NH Asian women to NH White women was greater among normal-weight women (aOR 3.48; 95% CI: 3.28, 3.70) as compared to overweight women (aOR 3.12; 95% CI: 2.87, 3.40).[17]

In our study, we found a greater risk of cesarean delivery for overweight/obese NH African-American women as compared to overweight/obese NH White women. Our finding was consistent with findings from other studies[18 19] where, compared with obese NH White women, the odds of cesarean delivery was greater for NH African-American (aOR 1.50; 95% CI: 1.04, 2.16 and p-value <0.05) and NH Asian women (aOR 1.73; 95% CI: 1.13, 2.63 and p-value <0.05). This was in contrast with Marshall et al. who reported that there was no difference in cesarean delivery risk between obese NH African-American women and obese NH White women (aOR 1.1; 95% CI: 1, 1.01 and p-value 0.216) and between morbidly obese NH African-American women (BMI $\geq$ 40 kg/m^2) and morbidly obese NH White women (aOR 1; 95% CI: 0.9, 1.2 and p-value 0.676).[16]

The differences in associations among NH White women, African/American women, or Asian women may be partly attributed to the fact that overweight or obesity status measured by BMI may underestimate body fat in NH Asian women[31] and overestimate in others. Many studies have noted that NH Asians have a lower BMI for the same body fat, age and sex, as compared to NH Whites, and that the overweight or obesity status measured by BMI may underestimate body fat in NH Asian women as compared to women of other race/ethnicities.[31] In an individual, the quantity of visceral adipose tissue (VAT), but not subcutaneous adipose tissue (SAT), predicts metabolic disease,[32 33] and at a given BMI, individuals of different race/ethnicity

may have very different amounts of VAT. Specifically, NH Asian Americans tend to have more VAT than NH Whites on average, while NH African Americans have less VAT and more SAT.[34] [35] The nonsignificant findings in the sensitivity analyses could suggest non-multiplicative (additive) interaction or even low statistical power, which needs further investigation. The difference in results of our primary analyses using universal BMI cut-offs and the sensitivity analyses using Asia Pacific BMI cut-offs could be due to interaction is stronger among more overweight or obese women that was captured by universal BMI cut-offs, in contrast to the Asia Pacific BMI that includes comparatively less obese women.

The difference in associations that were observed among different racial/ethnic groups may also be due to baseline risk differences for pregnancy complications among different racial/ethnic groups. No clear pattern (and related explanation) of interaction between race/ethnicity and pre-pregnancy overweight or obesity status on pregnancy complications has been described. Differences between findings of our study, compared with previous reports, may be related to differences in study population characteristics, adjustment variables, bias, or chance. Other factors that may account for the differences in observation that are not accounted for in the current study include diet, physical and social environment, health behaviors, and access to prenatal care, among others.

This study has both limitations and strengths that should be considered while interpreting the findings from this study. The sample size was large and the study population was diverse providing us with sufficient power to test interaction between race/ethnicity and pre-pregnancy overweight or obesity status; however, there might still be low power for assessing interactions related to race/ethnicity groups with smaller numbers. In addition, there could be a significant variation in characteristics within even a single race/ethnicity group. The OB COAP database is

a regularly audited, chart abstracted database that ensured high data quality for our analyses. Though these data are checked for consistencies, medical records maintained by multiple providers may contribute to some degree of misclassification. The self-reported measures in the study (e.g., self-reported race/ethnicity) may lead to misclassification as well. Missing values for several variables may lead to misclassification. However, it is unlikely that misclassification due to missing data will be differential due to the prospective cohort design of the study and outcome ascertainment. The measure of pre-pregnancy overweight or obesity status was BMI, which doesn't take into account the body fat distribution that vary between women of different race/ethnicities. The pre-pregnancy weight used to calculate the pre-pregnancy BMI was self-reported as well as collected at the prenatal visit when the self-report was not available, and we were not able to differentiate between these two from the data. Importantly, this may also vary by race. Another limitation is unavailability of other measures of socioeconomic status (SES). Using government health insurance (yes/no) as a proxy measure for SES may result in residual confounding as SES may not be completely captured by insurance type.[36] The prevalence of cesarean delivery in this population (16.1%) was relatively low compared to the state-wide cesarean delivery rate (27.7%) [37]. Our finding, supported by previous reports from OB COAP, shows an overall reduction in the rate of primary cesarean deliveries for OB COAP hospitals from 24.0% in 2011 to 15.7% in 2016.[38] Another limitation is that given the number of subgroup analyses performed in our study, we did not adjust for multiple comparisons and hence there is a chance of false positive results in our observed associations. Finally, the study was limited to births that occurred at the institutions participating in the OB COAP initiative. This may limit generalizability of study findings; however, the large size of deliveries included in the database

(a third of all WA state deliveries) as well as the broad mix of acuity (patient flow and adequacy of staffing) of participating facilities minimizes this concern.

While our study demonstrated an interaction between race/ethnicity and overweight or obesity status on pregnancy complications, there are continued opportunities of research in this area. This study did not consider possible mechanisms, and the role of additional factors for pregnancy complications, such as diet, genetics, or physical and social environment that could have been responsible for the interaction. We used BMI-defined overweight or obesity status and did not consider the difference in body composition between women of different race/ethnicities. A different measure of adiposity can be utilized to study if the differential association observed in this study persists after taking into account the body fat distribution.

For public health practice or clinical practice, focus on healthy preconception weight can be considered with an additional understanding of the potential differential association of pre-pregnancy overweight or obesity status with pregnancy complications across racial/ethnic groups. For example, overweight or obese women of certain racial groups, such as NH AI/AN women may benefit from a close surveillance for preeclampsia and even prophylactic low dose aspirin, as compared to NH White women.[39] In summary, in the OB COAP study population, we found that there is evidence of an interaction of race/ethnicity with pre-pregnancy overweight or obesity status on GDM, preeclampsia, and cesarean delivery. Future studies to confirm these associations and to identify a clear pattern of the differential relationship by race/ethnicity and pre-pregnancy overweight or obesity status along with studies that investigate the mechanisms of this interaction are needed. This will eventually contribute to better understanding of this complex relationship in order to better serve the maternal and child health population.

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Table 1. Selected Characteristics of Study Participants by Race/Ethnicity

Characteristics	NH White (N=29,857)	NH AA (N=2,515)	Hispanic (N=12,282)	NH Asian (N=11,056)	NH AI/AN (N=773)	NH PI (N=661)	All (N=57,144)
Age (years) Mean (SD)	29.9 (5.26)	29.2 (5.83)	27.4 (6.10)	31.5 (4.38)	26.9 (5.74)	28.2 (5.47)	29.6 (5.51)
Age (years)							
<20	2.4	4.5	9.6	0.3	8.5	4.8	3.7
20-24	13.7	17.6	25.5	4.9	28.7	21.9	15.0
25-29	29.3	29.9	28.9	26.4	31.3	32.8	28.8
30-34	34.8	28.4	21.7	44.1	19.4	25.3	33.2
35+	19.8	19.4	14.1	24.2	12.0	15.1	19.2
BMI (kg/m^2) Mean (SD)	26.8 (6.34)	28.0 (6.81)	28.5 (6.49)	23.6 (4.19)	30.2 (7.48)	30.7 (7.57)	26.7 (6.31)
BMI (kg/m^2)							
Underweight (<18.5)	1.9	2.7	1.6	5.4	1.6	0.8	2.6
Normal (18.5-24.9)	46.2	33.8	30.8	64.1	26.3	24.5	45.3
Overweight/Obese (≥25)	51.8	63.5	67.6	30.5	72.2	74.7	52.1
Health Insurance							
Non-government	69.7	33.6	21.2	82.0	24.2	42.1	59.1
Government	29.1	65.9	78.4	16.6	74.4	57.5	39.9
Parity							
Nulliparous (No birth)	24.3	17.5	19.4	29.8	23.8	16.2	23.9
Multiparous (1-4 births)	53.1	55.8	63.9	44.3	56.9	56.9	53.9
Grand multiparous (≥ 5)	1.3	5.9	2.7	0.2	5.7	5.3	1.7
Substance Abuse							
Yes	2.6	2.8	1.3	0.3	12.4	2.1	2.0
No	97.1	96.9	98.6	99.0	87.5	97.4	97.7
Nicotine Use							
Yes	8.9	7.1	2.5	1.1	17.6	12.7	6.1
No	90.4	91.3	92.1	89.0	81.8	86.7	90.4
Alcohol Use							
Yes	6.8	5.1	2.0	2.7	5.7	8.0	4.9
No	87.2	90.4	85.3	84.8	85.8	89.9	86.5
Weight gain during pregnancy (kg) Mean (SD)	12.6 (6.98)	10.2 (7.22)	10.2 (10.4)	11.7 (5.45)	10.6 (7.19)	11.2 (8.64)	11.8 (7.69)
Weight gain during pregnancy (kg)							
0-10	36.0	51.7	52.4	41.3	49.2	48.4	41.6
11-20	53.2	37.1	38.3	52.9	38.4	40.2	48.9
21-30	7.6	5.7	4.0	3.4	6.7	6.8	5.9
31-40	0.4	0.3	0.3	0.1	0.4	0.9	0.3
≥ 40	0.1	0.1	0.2	0.0	0.1	0.3	0.1
Gestational age (days) Mean (SD)	276 (12.5)	275 (14.9)	274 (13.0)	275 (12.0)	272 (13.7)	272 (15.7)	275 (12.7)
Gestational age (weeks)							
Preterm (≤ 36)	5.6	6.8	6.3	5.6	9.7	8.5	5.9
Early Term (37 0/7 – 38 6/7)	21.1	23.5	26.4	26.2	32.1	27.8	23.6
Full Term (39 0/7 – 40 6/7)	58.4	53.4	58.3	58.9	50.6	54.5	58.1
Late Term (41 0/7 – 41 6/7)	13.7	14.6	8.3	9.0	7.2	7.9	11.5
Post Term (> 42 0/7)	1.1	1.4	0.4	0.3	0.3	0.9	0.8
Birth Weight of baby (gram) Mean (SD)	3440 (534)	3290 (579)	3330 (527)	3210 (489)	3400 (561)	3320 (589)	3360 (534)
History of Cesarean delivery	2.5	4.8	3.0	2.5	2.1	4.4	2.7
Preeclampsia	10.5	10.9	7.3	5.8	12.1	8.0	8.9
Gestational Diabetes	7.9	9.8	9.9	17.1	8.0	16.6	10.3

Cesarean Delivery	15.5	21.4	12.9	21.4	13.6	20.1	16.1
Labor Type							
Induced	32.8	34.2	27.0	25.5	29.4	28.3	30.1
Spontaneous	64.4	62.5	69.6	71.4	68.2	68.4	66.9

*__NH:__ Non-Hispanic | __AI/AN:__ American Indian/Alaskan Native **|** __PI:__ Native Hawaiian and Other Pacific Islanders | __BMI:__ Body Mass Index | __SD:__ Standard Deviation

** Percentage, unless otherwise specified, Column percentages may not add up to 100 due to missing values

Table 2. Selected Characteristics of Study Participants by Pre-pregnancy Overweight or Obesity Status

Characteristics	Underweight (BMI <18.5 kg/m^2) (N=1,463)	Normal weight (BMI 18.5-24.9 kg/m^2) (N=25,892)	Overweight/Obese (BMI ≥25 kg/m^2) (N=29,789)	All (N=57,144)
Age (years) Mean (SD)	28.3 (5.49)	29.9 (5.43)	29.5 (5.57)	29.6 (5.51)
Age (years)				
<20	5.9	3.8	3.6	3.7
20-24	19.5	13.3	16.3	15.0
25-29	31.0	27.4	29.8	28.8
30-34	30.3	35.7	31.1	33.2
35+	13.1	19.7	19.2	19.2
Race/ Ethnicity				
NH White	39.8	53.3	51.9	52.2
NH African-American	4.7	3.3	5.4	4.4
Hispanic	13.5	14.6	27.9	21.5
NH Asian	40.8	27.4	11.3	19.3
NH AI/AN	0.8	0.8	1.9	1.4
NH Native-Hawaiian/ Other PI	0.3	0.6	1.7	1.2
Health Insurance				
Non-government	61.7	68.1	51.2	59.1
Government	37.2	30.7	47.9	39.9
Parity				
Nulliparous (No birth)	32.3	27.3	20.5	23.9
Multiparous (1-4 births)	42.2	50.4	57.7	53.9
Grand multiparous (≥ 5 births)	0.5	0.8	2.5	1.7
Substance Abuse				
Yes	1.4	1.6	2.3	2.0
No	98.2	98.0	97.3	97.7
Nicotine Use				
Yes	5.1	4.6	7.5	6.1
No	88.9	91.0	89.9	90.4
Alcohol Use				
Yes	3.0	4.5	5.4	4.9
No	86.2	86.1	86.8	86.5
Weight gain during pregnancy (kg) Mean (SD)	14.7 (8.13)	13.5 (5.43)	10.2 (8.9)	11.8 (7.69)
Weight gain during pregnancy (kg)				
0-10	27.7	30.9	51.5	41.6
11-20	63.4	60.8	37.8	48.9
21-30	4.9	6.7	5.3	5.9
31-40	0.5	0.3	0.3	0.3
≥ 40	2.5	0.1	0.1	0.1
Gestational age (days) Mean (SD)	274 (11.9)	276 (11.8)	275 (13.5)	275 (12.7)
Gestational age (weeks)				
Preterm (≤ 36)	6.0	5.0	6.6	5.9
Early Term (37 0/7 – 38 6/7)	28.9	22.7	24.1	23.6
Full Term (39 0/7 – 40 6/7)	56.4	59.9	56.7	58.1
Late Term (41 0/7 – 41 6/7)	8.0	11.5	11.7	11.5
Post Term (> 42 0/7)	0.5	0.8	0.8	0.8
Birth Weight of baby (grams) Mean (SD)	3170 (476)	3330 (507)	3400 (556)	3360 (534)
History of Cesarean delivery	1.2	2.3	3.2	2.7
Preeclampsia	5.5	5.2	12.4	8.90

Gestational Diabetes	6.1	7.2	13.2	10.3
Cesarean Delivery	10.5	14.0	18.3	16.1
Labor Type				
Induced	22.0	25.1	34.8	30.1
Spontaneous	76.2	72.4	61.5	66.9

*__NH:__ Non-Hispanic | __AI/AN:__ American Indian/Alaskan Native __| PI:__ Pacific Islander __| BMI:__ Body Mass Index | __SD:__ Standard Deviation

** Percentage, unless otherwise specified, Column percentages may not add up to 100 due to missing values

Table 3. Independent Associations of Race/Ethnicity and Pre-pregnancy Overweight or Obesity Status with Pregnancy Complications

	Gestational Diabetes			Preeclampsia			Cesarean Delivery		
	n	**RR**	**aRR**	**n**	**RR**	**aRR**	**n**	**RR**	**aRR**
Maternal Race/Ethnicity									
NH White	2057	Ref.	Ref.	2599	Ref.	Ref.	4539	Ref.	Ref
NH African-American	206	**1.21 (1.06, 1.39)**	**1.36 (1.16, 1.59)**	205	0.96 (0.84, 1.09)	1.03 (0.86, 1.23)	537	**1.40 (1.30, 1.52)**	**1.72 (1.55, 1.91)**
Hispanic	1119	**1.30 (1.22, 1.40)**	**1.44 (1.31, 1.58)**	778	**0.72 (0.66, 0.78)**	**0.89 (0.80, 0.99)**	1557	**0.83 (0.79, 0.88)**	1.05 (0.97, 1.14)
NH Asian	1810	**2.34 (2.20, 2.48)**	**2.12 (1.97, 2.28)**	562	**0.57 (0.53, 0.63)**	**0.53 (0.47, 0.59)**	2349	**1.40 (1.34, 1.46)**	**1.17 (1.09, 1.24)**
NH AI/ AN	52	0.98 (0.75,1.28)	1.25 (0.93,1.67)	77	1.15 (0.93, 1.43)	**1.42 (1.10, 1.84)**	104	0.88 (0.74, 1.06)	1.15 (0.91, 1.45)
NH Native-Hawaiian/Other PI	82	**1.89 (1.54, 2.33)**	**2.42 (1.92, 3.04)**	38	**0.69 (0.51, 0.95)**	**0.64 (0.42, 0.98)**	133	**1.32 (1.13, 1.54)**	**1.81 (1.49, 2.19)**
Pre-pregnancy Overweight or Obesity Status									
Normal Weight (BMI 18.5-24.9 kg/m^2)	1790	Ref.	Ref.	1197	Ref.	Ref.	3618	Ref.	Ref.
Overweight/Obese (BMI ≥25 kg/m^2)	3452	**1.73 (1.64, 1.83)**	**1.92 (1.80, 2.05)**	2991	**2.24 (2.10, 2.39)**	**2.57 (2.36, 2.80)**	5447	**1.31 (1.26, 1.36)**	**1.58 (1.50, 1.67)**

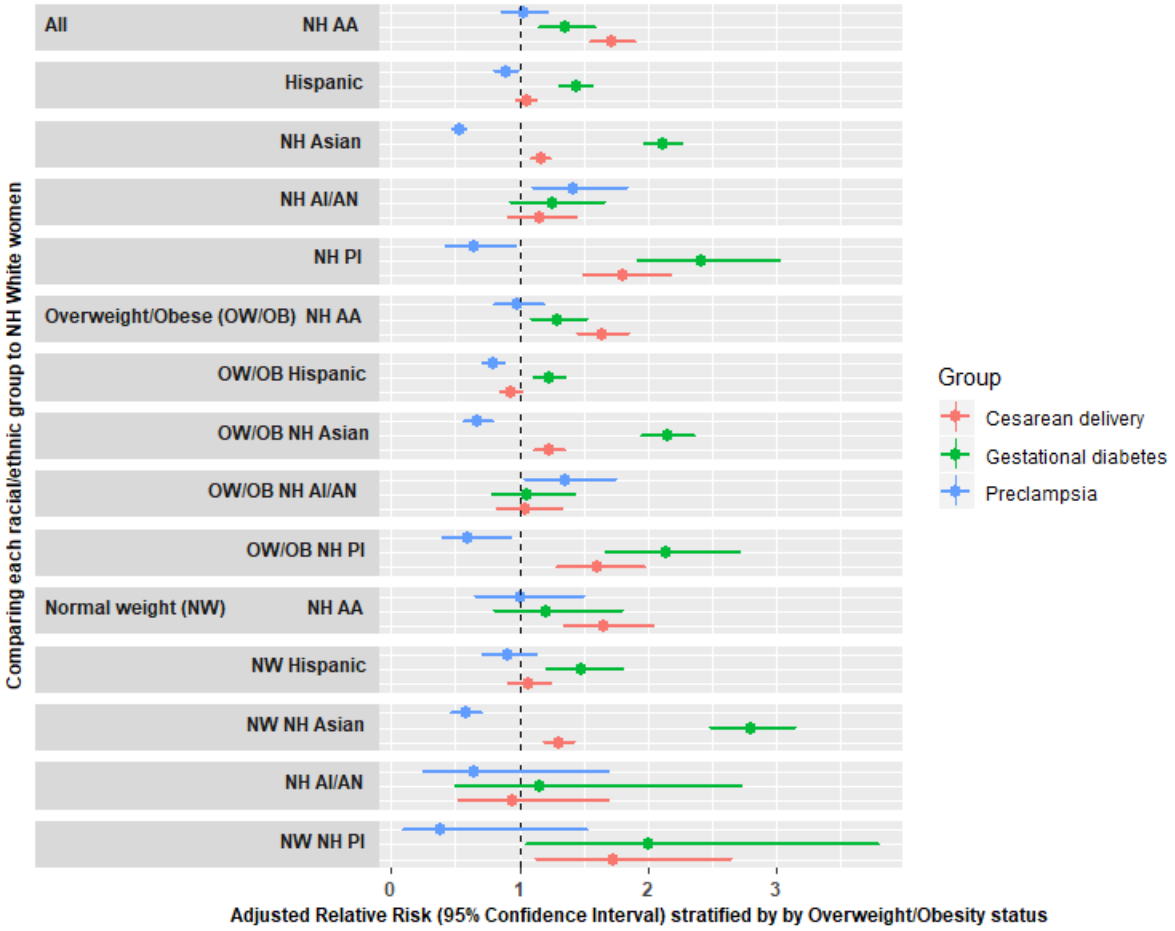
RR: Relative Risk | **CI:** Confidence Interval | **aRR**: Adjusted RR controlled for maternal age (in years), parity, delivery hospital, government health insurance (yes/no), substance abuse started or continued during the pregnancy (yes/no), nicotine use started or continued during pregnancy (yes/no) and alcohol use started or continued during pregnancy (yes/no) | **NH**: Non-Hispanic | **AI/AN**: American Indian/ Alaskan Native | **PI:** Pacific Islander | **BMI:** Body Mass Index

Table 4. Associations of Race/Ethnicity with Pregnancy Complications Among Women Stratified by Pre-pregnancy Overweight or Obesity Status

Race/ Ethnicity	Gestational Diabetes						Preeclampsia						Cesarean Delivery					
	Normal Weight (BMI 18.5-24.9 kg/m^2)			Overweight/ Obese (BMI ≥25 kg/m^2)			Normal Weight (BMI 18.5-24.9 kg/m^2)			Overweight/ Obese (BMI ≥25 kg/m^2)			Normal Weight (BMI 18.5-24.9 kg/m^2)			Overweight/ Obese (BMI ≥25 kg/m^2)		
	n	**RR**	**aRR**	**n**	**RR**	**aRR**	**n**	**RR**	**aRR**	**n**	**RR**	**aRR**	**n**	**RR**	**aRR**	**n**	**RR**	**aRR**
NH White	604	Ref	Ref	1426	Ref	Ref	737	Ref	Ref	1821	Ref	Ref	1636	Ref	Ref.	2860	Ref	Ref
NH African-American	31	0.84 (0.59, 1.19)	1.21 (0.81, 1.80)	174	**1.21 (1.05, 1.41)**	**1.29 (1.09, 1.53)**	42	0.93 (0.69, 1.26)	1.01 (0.66, 1.51)	158	0.86 (0.74, 1.0)	0.98 (0.80, 1.19)	162	**1.61 (1.39, 1.86)**	**1.66 (1.34, 2.05)**	366	**1.24 (1.13, 1.36)**	**1.64 (1.45, 1.86)**
Hispanic	177	1.06 (0.90, 1.25)	**1.48 (1.20, 1.82)**	939	**1.20 (1.11, 1.29)**	**1.23 (1.11, 1.37)**	150	**0.74 (0.62, 0.87)**	0.90 (0.71, 1.14)	623	**0.62 (0.57, 0.68)**	**0.79 (0.70, 0.89)**	387	**0.86 (0.78, 0.96)**	1.07 (0.91, 1.25)	1154	**0.75 (0.71, 0.80)**	0.93 (0.84, 1.03)
NH Asian	959	**3.07 (2.79, 3.39)**	**2.83 (2.49, 3.15)**	798	**2.54 (2.35, 2.74)**	**2.16 (1.96, 2.37)**	253	**0.66 (0.58, 0.76)**	**0.58 (0.47, 0.70)**	291	**0.72 (064, 0.82)**	**0.67 (0.57, 0.79)**	1382	**1.64 (1.54, 1.76)**	**1.31 (1.19, 1.43)**	883	**1.42 (1.33, 1.51)**	**1.24 (1.12, 1.36)**
NH AI/ AN	5	0.56 (0.23, 1.34)	1.16 (0.49, 2.74)	47	0.92 (0.70, 1.21)	1.06 (0.78, 1.44)	11	1.01 (0.56, 1.80)	0.64 (0.24, 1.70)	64	0.98 (0.77, 1.24)	**1.36 (1.04, 1.76)**	22	0.91 (0.61, 1.36)	0.94 (0.52, 1.70)	81	**0.78 (0.64, 0.96)**	1.05 (0.82, 1.34)
NH Native-Hawaiian/ Other PI	14	**1.98 (1.19, 3.30)**	**2.0 (1.05, 3.8)**	68	**1.58 (1.26, 1.98)**	**2.14 (1.67, 2.73)**	4	0.46 (0.18, 1.23)	0.38 (0.09, 1.53)	34	**0.62 (0.45, 0.86)**	**0.60 (0.39, 0.94)**	29	**1.51 (1.08, 2.11)**	**1.73 (1.13, 2.66)**	103	1.13 (0.95, 1.34)	**1.6 (1.29, 1.98)**

RR: Relative Risk | **CI:** Confidence Interval | **aRR**: Adjusted RR controlled for maternal age (in years), parity, delivery hospital, government health insurance (yes/no), substance abuse started or continued during the pregnancy (yes/no), nicotine use started or continued during pregnancy (yes/no) and alcohol use started or continued during pregnancy (yes/no) | **NH**: Non-Hispanic | **AI/AN**: American Indian/ Alaskan Native | **PI:** Pacific Islander | **BMI:** Body Mass Index

Figure 1. Associations of Race/Ethnicity with Pregnancy Complications Among Women Stratified by Pre-pregnancy Overweight or Obesity Status



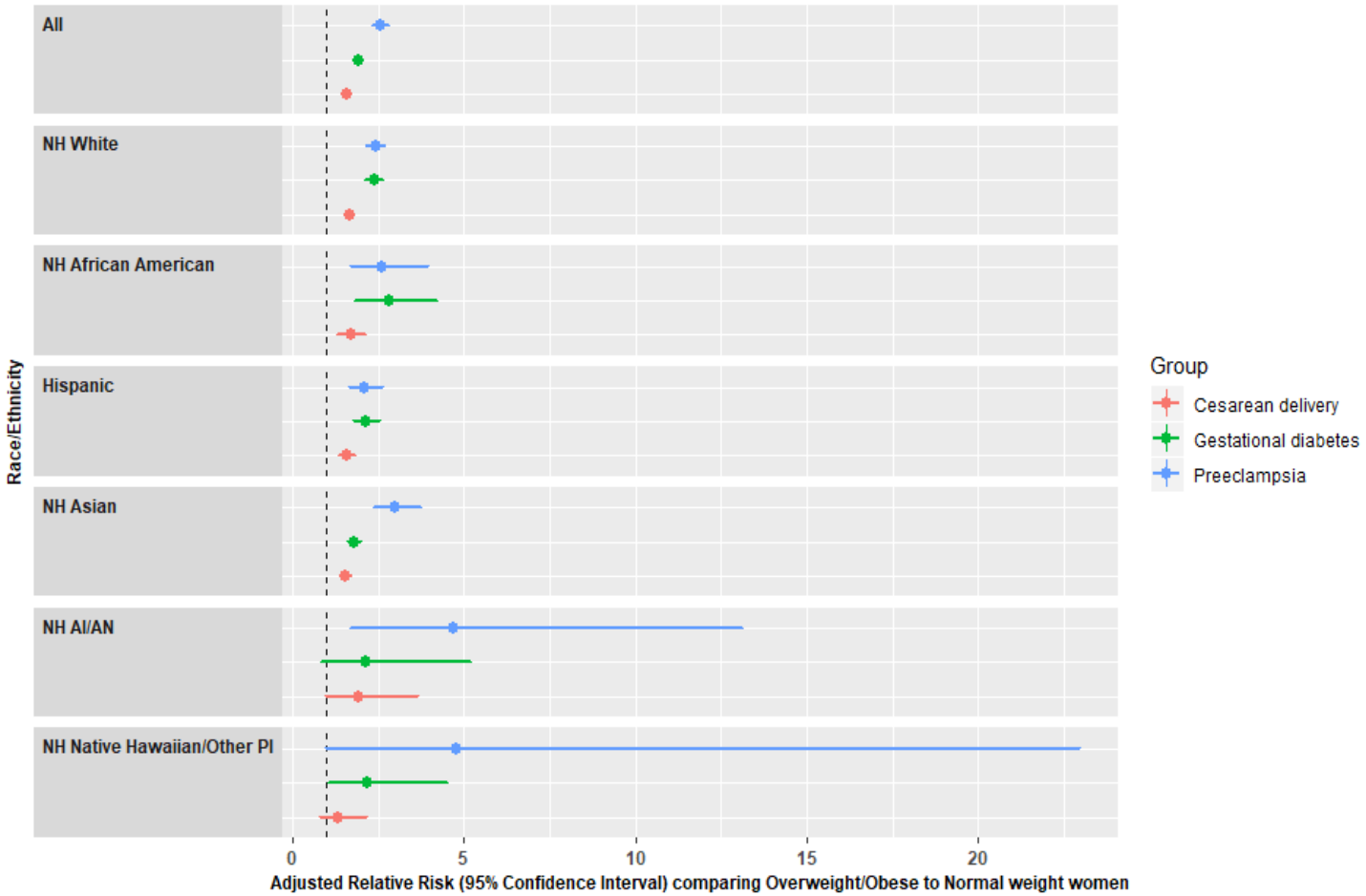
Adjusted RR controlled for maternal age (in years), parity, delivery hospital, government health insurance (yes/no), substance abuse started or continued during the pregnancy (yes/no), nicotine use started or continued during pregnancy (yes/no) and alcohol use started or continued during pregnancy (yes/no) | **NH**: Non-Hispanic | **AA:** African-American | **AI/AN**: American Indian/ Alaskan Native | **PI:** Native-Hawaiian/Other Pacific Islander

Table 5. Associations of Pre-pregnancy Overweight or Obesity Status with Pregnancy Complications Among Women Stratified by Race/Ethnicity

Race/ Ethnicity	Gestational Diabetes						Preeclampsia						Cesarean Delivery					
	Normal Weight (BMI 18.5-24.9 kg/m^2)			Overweight/Obese (BMI ≥25 kg/m^2)			Normal Weight (BMI 18.5-24.9 kg/m^2)			Overweight/Obese (BMI ≥25 kg/m^2)			Normal Weight (BMI 18.5-24.9 kg/m^2)			Overweight/Obese (BMI ≥25 kg/m^2)		
	n	RR	aRR	n	RR	aRR	n	RR	aRR	n	RR	aRR	n	RR	aRR	n	RR	aRR
NH White	604	Ref.	Ref.	1426	**2.18 (1.99, 2.39)**	**2.38 (2.13, 2.64)**	737	Ref.	Ref.	1821	**2.28 (2.10, 2.47)**	**2.43 (2.19, 2.69)**	1636	Ref.	Ref.	2860	**1.56 (1.47, 1.65)**	**1.66 (1.54, 1.78)**
NH African-American	31	Ref.	Ref.	174	**3.16 (2.18, 4.59)**	**2.80 (1.85, 4.24)**	42	Ref.	Ref.	158	**2.12 (1.52, 2.95)**	**2.59 (1.69, 3.97)**	162	Ref.	Ref.	366	**1.20 (1.02, 1.42)**	**1.69 (1.34, 2.13)**
Hispanic	177	Ref.	Ref.	939	**2.46 (2.11, 2.88)**	**2.14 (1.78, 2.56)**	150	Ref.	Ref.	623	**1.93 (1.62, 2.29)**	**2.1 (1.68, 2.63)**	387	Ref.	Ref.	1154	**1.36 (1.22, 1.51)**	**1.59 (1.37, 1.84)**
NH Asian	959	Ref.	Ref.	798	**1.80 (1.66, 1.96)**	**1.79 (1.61, 1.99)**	253	Ref.	Ref.	291	**2.49 (2.12, 2.94)**	**3.0 (2.39, 3.76)**	1382	Ref.	Ref.	883	**1.34 (1.25, 1.45)**	**1.54 (1.39, 1.71)**
NH AI/ AN	5	Ref.	Ref.	47	**3.59 (1.44, 8.93)**	2.11 (0.86, 5.19)	11	Ref.	Ref.	64	**2.22 (1.19, 4.14)**	**4.70 (1.69, 13.11)**	22	Ref.	Ref.	81	1.34 (0.86, 2.09)	1.90 (0.98, 3.67)
NH Native Hawaiian/ Other PI	14	Ref.	Ref.	68	**1.74 (1.0, 3.0)**	**2.19 (1.06, 4.51)**	4	Ref.	Ref.	34	**3.04 (1.09, 8.47)**	4.76 (0.99, 22.96)	29	Ref.	Ref.	103	1.17 (0.80, 1.69)	1.32 (0.84, 2.17)

RR: Relative Risk | **CI**: Confidence Interval | | **aRR**: Adjusted RR controlled for maternal age (in years), parity, delivery hospital, government health insurance (yes/no), substance abuse started or continued during the pregnancy (yes/no), nicotine use started or continued during pregnancy (yes/no) and alcohol use started or continued during pregnancy (yes/no) | **NH**: Non-Hispanic | **AI/AN**: American Indian/ Alaskan Native | **PI:** Pacific Islander | **BMI:** Body Mass Index

Figure 2. Associations of Pre-pregnancy Overweight or Obesity Status with Pregnancy Complications Among Women Stratified by Race/Ethnicity



Adjusted RR controlled for maternal age (in years), parity, delivery hospital, government health insurance (yes/no), substance abuse started or continued during the pregnancy (yes/no), nicotine use started or continued during pregnancy (yes/no) and alcohol use started or continued during pregnancy (yes/no) | **NH**: Non-Hispanic | **AI/AN**: American Indian/ Alaskan Native | **PI:** Pacific Islander

Table 6. Associations of Race/Ethnicity and Pre-pregnancy Overweight or Obesity Status with Pregnancy Complications– Sensitivity Analysis Using Asia Pacific BMI cut off

Comparison	Gestational Diabetes			Preeclampsia			Cesarean Delivery		
	n	RR	aRR	n	RR	aRR	n	RR	aRR
NH Asian vs NH White									
Overweight/ Obese (NH Asian BMI ≥23 kg/m^2 or NH White BMI ≥25 kg/m^2)	1148	**2.23 (2.08, 2.40)**	**1.90 (1.74, 2.08)**	365	**0.56 (0.50, 0.62)**	**0.50 (0.43, 0.58)**	1367	**1.36 (1.28, 1.43)**	**1.15 (1.06, 1.25)**
Normal Weight (NH Asian BMI 18.5-22.9 kg/m^2 or NH White BMI 18.5-24.9 kg/m^2)	609	**2.76 (2.48, 3.07)**	**2.54 (2.23, 2.90)**	179	**0.66 (0.57, 0.78)**	**0.57 (0.46, 0.72)**	898	**1.51 (1.40, 1.63)**	**1.19 (1.07, 1.32)**
Overweight/Obese vs Normal Weight									
NH Asian (Overweight/Obese BMI ≥23 kg/m^2 vs. Normal Weight BMI 18.5-22.9 kg/m$^{2)}$	1148	**1.77 (1.61, 1.93)**	**1.74 (1.55, 1.94)**	365	**1.91 (1.60, 2.27)**	**2.20 (1.72, 2.81)**	1367	**1.40 (1.29, 1.50)**	**1.56 (1.40, 1.73)**

RR: Relative Risk | **CI**: Confidence Interval | **aRR**: Adjusted RR controlled for maternal age (in years), parity, delivery hospital, government health insurance (yes/no), substance abuse started or continued during the pregnancy (yes/no), nicotine use started or continued during pregnancy (yes/no) and alcohol use started or continued during pregnancy (yes/no) | **NH**: Non-Hispanic | Reference category is NH White women | **BMI:** Body Mass Index